The effect of salivary pH on diametral tensile strength of resin modified glass ionomer cement coated with coating agent

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Abstract. The aim of this study was to evaluate the effect of artificial saliva with different acidities on the diametral tensile strength of Resin Modified Glass Ionomer Cement (RMGIC) coated with *varnish* and nanofilled coating agent. The specimens coated with coating agents were immersed in artificial saliva with pH of 4.5, 5.5, and 7 for 24 hours in an incubator at 37^{o}C. The diametral tensile strength of the specimens was tested with Universal Testing Machine. There were no significant differences on the diametral tensile strength of all specimens that were put into groups based on the acidity of the saliva and the type of coating agent ($p>0.05$). Both varnish and nanofilled coating agent stayed on the RMGIC in the acidic condition that simulated the true condition of oral cavity in people with high caries risk for the 24 hours of maturation.

1. Introduction

Glass Ionomer Cement (GIC) is one of the most widely used restoration materials, especially for people who have a high caries risk because of its ability to release fluoride. GIC has been widely used because of many advantages found in this cement, such as the ability to chemically bond with tooth structure, similar thermal compatibility to email, and excellent biocompatibility [1-4]. However, beside to the advantages GIC also has some disadvantages, such as low mechanical strength and susceptible to acidity and humidity. The exposure of cement by water can cause surface erosion, decreased strength, small cracks in the restoration, and decreased adhesion strength of this material [5]. This may cause micro leakage that will result in a failure of the restoration.

Resin Modified Glass Ionomer Cement (RMGIC) is the result of GIC modification that is created to eliminate such deficiencies. Some resin components such as *HEMA* (*hydroxyetyl methacrylate*) and photoinitiator are added to this material, so the setting reaction is done through two mechanisms, such as acid-base reaction and free-radical polymerization reaction of *HEMA* that can occur by the initiation of chemical reactions and irradiation. With the addition of this resin compound, RMGIC has been stated to be more resistant to humidity than conventional GIC. However, in reality, the application of coating agent is still needed in RMGIC, because after all, most of the setting process is an acid-base reaction, which in the early 24 hours is still very sensitive to water [6]. Application of coating agent on RMGIC is strongly recommended to protect the restoration during initial setting reactions.Many types of coating agents can be used to prevent direct exposure of the restoration from saliva, but it is not known whether these materials can survive in saliva with a low pH that is commonly found in patients with high caries risk. This acid condition may cause degradation of ionomer cement and resin

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materials [7]. It is important to note because resin is used as a base material in varnish and nanofilled coating agent.

Effect of saliva with different pH on the mechanical strength of RMGIC that is coated with varnish coating agents and nanofilled coating agent, can be seen through diametral tensile strength. The diametral tensile strength test is a test that measures the strength of a material against a force that causes the material to stretch before breaking [2]. This test is the most widely used to measure the tensile strength of a fragile material such as a glass ionomer.In this study will be reviewed further about the effect of artificial saliva with pH 4.5, 5.5, and 7 on the diametral tensile strength of RMGIC coated agent with varnish and nanofilled coating agent

2. Materials and Methods

2.1 Specimen Preparation

This is a laboratory experimental study.Specimen shape and preparationaccording to ADA specification number 66 in 1989. Specimens used in this study are RMGIC GC Fuji II LC (GCAmerica Inc., Alsip, IL, USA). RMGIC are manipulated according to the required amount of each group. After obtaining a homogenous mixture of RMGIC, the cement is placed into a stainless steel moldwith a diameter of 6 mm and height of 3 mm until it is full. Mylar plastic and glass slab are placed on the specimen then pressed with a load of 1 kg on it.

2.2 Polymerization with Light-Curing Unit (LCU)

After the excess cement comes out of the mold, the load is lifted from the glass slab and cured with LCU for 20 seconds. After the top of the cement is polymerized, the mold is opened with a screwdriver and the specimen is removed from the mold. Then the sides of the specimen are clamped with tweezers, and the opposite side of the first curing direction is cured for 20 seconds.

2.3 Coating Agent Application and Immersion

After the specimens were removed from the mold, the entire surface was covered with varnish using microbrush, and allowed to dry for 2 minutes. Then the specimen is immersed into artificial saliva pH 4.5, 5.5, and 7 for 24 hours in an incubator with temperature 37^{o}C.

2.4 Diametral Tensile Strength Test

Diametral tensile strength test is performed by using Shimadzu Universal Testing Machine (Shimadzu Corporation, Kyoto, Japan) with a maximum compression load of 250 kgf at a crosshead speed of 0.5 mm/min. In this test, the material that has been moulded in a disk-shaped is given a compression pressure until fracture is visible. From the diametral tensile strength value of the specimen, calculation of mean and standard deviation values is performed.

3. Results and Discussion

3.1 Results

The mean value of the diametral tensile strength of RMGIC coated with varnish or the nano-filled coating agent for immersion in artificial saliva with pH of 4.5, 5.5, and 7 for 24 hours can be seen in Table 1.

Table 1. Diametral tensile strength value of RMGIC which have been coated with coating agent and immersed in artificial saliva with different pH

Artificial Saliva pH	Mean Value of Diametral Tensile Strength (MPa) ± SD	
	Varnish	Nanofilled coating agent
7	28.65±2.27	28.83±1.88
5.5	28.78±1.28	28.78±1.27
4.5	28.74±1.11	28.75±1.77

The data distribution was normal and homogeneous, then, a one-way ANOVA statistical test was conducted to see the significant differences between each group of RMGIC specimens. The results of one-way ANOVA statistical analysis showed no significant differences between groups of RMGIC specimens. Subsequently, a PostHoc test was conducted using the LSD method to see the specimen groups that had significant differences in the diametral tensile strength value. Based on the results of this test, it was found that there was no significant difference between groups of specimens immersed in artificial saliva pH 4.5 and pH 5.5, between groups of specimens immersed in artificial saliva pH 5.5 and 7, and between groups of specimens immersed in artificial saliva pH 4.5 and 7.

Independent Sample t-Test was conducted to compare the mean value between varnish-coated specimens and specimen group coated with nanofilled coating agent on artificialsaliva immersion pH 4.5, 5.5, and 7. The mean value of the diametral tensile strength in specimens group coated with nanofilled coating agent on artificial saliva immersion pH 4.5, 5.5, and 7 were respectively 0.397, 0.914, and 0.731 or $p > 0.05$. Thus, it can be concluded that there is no mean difference between the varnish-coated specimen group and the specimen group coated with nanofilled coating agent.

3.2 Discussion

In this study, Resin Modified Glass Ionomer Cement specimens which have been coated by two types of coating agent were immersed in artificial saliva with different pH. The types of coating agents used were varnish and nano filled coating agent. Application of both types of coating agent to the specimens were performed to evaluate the material resistance in protecting the RMGIC specimens in saliva environments either normal or acidic pH. The resistance of both coating agents in acidic condition can be accessed through a diametral tensile strength test conducted after the immersion. In this study, artificial saliva is used with pH 4.5 and 5.5 to simulate oral cavity with acid conditions in individuals with high and moderate caries risk, while artificial saliva with pH 7 was used to simulate oral cavity conditions with normal acidity levels at individuals with low caries risk. The results of this study indicate that the immersion of RMGIC specimens that have been coated with both coating agent in artificial saliva pH 4.5, 5.5, and 7 for 24 hours has no significant effect on the diametral tensile strength of RMGIC. This is supported by the result of diametral tensile strength test of 6 groups of RMGIC specimens which can be seen in Table 1.

No statistical significant difference between the mean results of the diametral tensile strength test of RMGIC is due to the varnish and nanofilled coating agent that is not significantly affected by the acid component of artificial saliva. According to the American Dental Association declaration in 1990, varnish and resin-based coating agent which is polymerized by light curing are the two most effective types of coating agent for glass ionomer restoration [8]. Varnish is considered an effective coating agent because of its ability to prevent dehydration in glass ionomer material. Based on research conducted by Nicholson *et al* (2007), applying varnish to cement as soon as it hardened is an early protective step that can prevent dehydration in cement. In addition, based on research conducted by Khosla *et al*. the application of varnish on glass ionomer restorations before the cement is exposed to APF gel 1.23% which have pH of 3.5, proven to help in perfect cement maturationand prevent glass ionomer particle degradation by phosphoric acid contained in the gel [9].

Another study by Hotta *et al* states that the use of a resin-based coating agent which is polymerized by light, may limit the occurrence of hydration and dehydration on the surface of the cement [10]. Later, it was discovered the development of resin–based coating agent called nanofilled coating material on the surface of the glass ionomer restoration. This nanofilled resin coating agent has low self-adhesive and low viscosity properties. In addition, the nanofiller component contained in this material also makes it more resistant to abrasion caused by frictional forces and mastication load in the oral cavity [3]. In a study conducted by Reddy, *et al* the nanofilled coating agent was also proven to protect glass ionomer material immersed in citric acid solution with pH 2, 3, 4, 5, 6, and 7.

RMGIC itself is a restorative material that has been reported to be more resistant to water compared to conventional GIC because of the additional components contained, such as hydrophilic resin monomers (*HEMA*) and photo-initiator. Some factories that produce RMGIC even instruct that

RMGIC can be used with or without coating agent. However, based on research conducted by Sidhu, *et al* the addition of resin monomers and photopolymerization components to RMGIC cannot significantly decrease the susceptibility of RMGIC to water. One of the objectives of the research is to prove the theory that one of the disadvantages of glass ionomer material is its susceptibility to desiccation. The method used in the study was a RMGIC specimen that was dehydrated for some time, and then rehydrated using a wet cotton wool and allowed to remain moist for 60 minutes. The results of the study showed that dehydrated RMGIC specimens were found to have small cracks on the surface. However, after rehydration, the cracks appear to be reduced, although it is unlikely that their chemical bonds will recover as before the specimens were treated. This is because of glass ionomer material is reported to have a "self-healing" nature or the material's ability to improve after dehydration [11]. From this study it can be concluded that RMGIC still has sensitivity to moisture properties as conventional GIC.

This is then confirmed by the results of research conducted by Jevnikar, *et al*. In this study, the diffusion of water into the RMGIC was monitored from MR micro-imaging. After immersion of RMGIC which has been placed on the teeth for 24 hours in water, water absorption was found on the surface of RMGIC that was not coated by coating agent, while the surface of RMGIC protected by coating agent showed different result, such as no water diffuses into RMGIC due to the protection of coating agent in the surfaces. In this study also mentioned that the photo-polymerization reaction contained in RMGIC cannot prevent the absorption of water into the cement.

The results of both studies can be explained by a study conducted by Lohbauer, which says although some resin components have been added to the cement, the acid-base reaction remains the dominant setting reaction, while the photopolymerization reaction is only an additional reaction. The acid-base reaction occurring in the setting process of this material is the same as conventional glass ionomer cement, only 4-6% of this cement is hardened by polymerization [12]. Therefore, some of the basic properties of conventional GIC are still commonly found in this material, such as its ability to chemically bond to tooth structure, its thermal compatibility similar to email, and its excellent biocompatibility. However, beside the advantages found in conventional GIC, RMGIC also has some disadvantages that are also found in conventional GIC. The sensitivity to humidity when the initial setting reaction is still on-going (during the first 24 hours) is one of the disadvantages of conventional GIC which is also owned by RMGIC. This sensitivity to humidity can inhibit the maturation process of the glass ionomer material. Water diffusion through the surface of a glass ionomer material that is not protected by a coating agent may cause a disruption of the acid-base reaction of the glass ionomer component present in the RMGIC. In the process of setting, glass particles of cement release Ca and Al ions which will form the matrices. However, if a liquid contact directly with the cement before the cement is fully hardened, the ions will be dissolved by water, so that the formation of the matrix will be disturbed. The disturbance of matrix formation will then have an effect on the decreasing mechanical strength of the material.

Another thing that can adversely affect the glass ionomer material is acid. The exposure of cement to an acid can cause erosion on the surface of the cement and dissolution of the substances that compose the matrix in it. This theory is proven by research conducted by Wan Bakar, which found the occurrence of surface damage on conventional GIC and RMGIC which is not covered with coating agent and exposed to acid. In the study, the conventional GIC and RMGIC specimens were immersed in three acid solutions, such as HCl solution with pH 1.2, citric acid solution with pH 2.13, and a phosphoric acid solution with a pH of 2.74. The results of these studies indicate the damage of each surface of the glass ionomer material caused by the erosive effect of the acid, although when compared to conventional GIC, the damage found in RMGIC is not significant. The study also showed that HCl is the most potential acid to damage the surface of RMGIC. Observations made using electron probes; it was found that HCl can dissolve some of the important elements present in RMGIC such as strontium, aluminum, fluor and phosphate up to 50 μm depth [13]. The susceptibility of RMGIC to these should be consideration the clinical use of materials. One of the recommendations to use RMGIC is to restore caries in a group of people who have high caries risk, whereas the relatively

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acidic condition of the oral cavity in people who have high caries risk may cause bad impact on the restoration.

Based on the research results above, it can be seen that the use of coating agent on the surface of RMGIC is very important in order to protect the restorative materials. The use of coating agent is particularly recommended for restorations that use RMGIC in people with high caries risk, due to the moist and acidic conditions in the oral cavity that may interfere with the initial stages of RMGIC. The results of this study indicate that the two coating agents, such asvarnish and nanofilled coating agent, are able to survive very well in artificial saliva pH 4.5, 5.5, and 7, which in this case represent the oral cavity in a group of people with high, medium, and low caries risk. Coating agent's ability to remain on a restoration for long periods in the oral cavity, helps restoration materials that require long maturation processes, such as RMGIC which takes 24 hours to fully mature. This is need to be concerned because the maturation process of RMGIC will affect the physical and mechanical properties of cement in the future, such as the ability of restoration to accept the load and forces caused by the process of mastication. The mechanical force in the process of mastication also needs to be a concern in choosing varnish as a coating agent, as it differs from the nanofilled coating agent which have nano filler particle size and is self-adhesive, varnish can be more easily removed by mastication in the mouth [13]. In this study, the immersion of RMGIC specimen which has been coated with coating agent in artificial saliva pH 4.5, 5.5, and 7 is done without applying mechanical force on coating agent. Therefore, further research is needed on the effect of saliva on RMGIC which has been coated with varnish and given mechanical force such as brushing.

4. Conclusion

The conclusion of this study was salivary pH did not affect the diametral tensile strength of the RMGIC that coated with varnish and nanofilled coating agent, so both types of coating agent could be used to protect the RMGIC during its 24-hour maturation process in a group of people with high caries risk**.**

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